NOTE ON THE SYSTEMATIC ERRORS IN BOSS'S PROPER MOTIONS

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In his interesting paper in *Bulletin of the Astronomical Institutes of the Netherlands* No. 14, Kapteyn has suggested that the proper motions in Boss's *Preliminary General Catalogue* are affected by serious systematic errors. His investigations are based on the following facts in addition to the catalogue comparisons:

1. The determination of the Solar Apex from the stars in Boss's catalogue[1] gives D=+35°.2 whereas determinations by means of radial velocities[2] give D=+25°.2. More recent results from radial velocities are those of Strömberg[3], +29°.2, and Forbes[4] +27°.

2. The helium stars although having a high galactic concentration, do not participate in the general star streaming, the little motion they do show being different from both stream I and II. At the same time it was shown by Kapteyn that stars lying in the plane of the Milky Way can have no other motion than stream motion with possibly some peculiar motion in the galactic plane.

All these discordances have been satisfactorily removed by Kapteyn by applying a correction to the $\mu\delta$ of 0″.013 cos δ, which value agrees perfectly with the one found from catalogue comparisons. It may be interesting to see how the position of the apex thus corrected will agree with the determinations from stars of large proper motion, on which the corrections will have only a small influence.

Dyson[5] finds from stars with proper motions between 0″.2 and 0″.8 annually D=+42°; Beljawsky[6], from Porter's proper motion stars +36°; Raymond[7], from Boss stars with proper motions between 0″.2 and 0″.8 +31°.5 and for proper motions

[1] *Mon. Not. R. A. S.*, **71**, 4, 1911 and *Astr. Jour.*, **26**, 187, 1911.
[2] *Lick Obs. Bull.*, **6**, 125, 1911.
[3] *Mt. Wilson Contributions*, No. **144**.
[4] *Mon. Not. R. A. S.*, **82**, 174, 1922.
[5] *Proc. Roy. Acad. Edin.*, **28**, 231, 1908; **29**, 376, 1909.
[6] *Astr. Nach.*, **179**, 298, 1908.
[7] *Astr. Jour.*, **30**, 197, 1917.

$<0''.2+32°.5$; the difference in the last two results being in the right sense according to Kapteyn's corrections but hardly large enough. The writer himself found for the apex from 700 stars with proper motions exceeding $0''.5$ annually $D=+40°.6$. No one of these determinations would be affected by Kapteyn's correction by more than a few degrees. On the other hand, we must bear in mind the fact that a few stars with high linear velocity may be largely responsible for these high declinations. Using the same material as before but using a method giving more weight to the larger velocities, the writer found $D=+45°.1$ and by rejecting the high velocity stars altogether, $+36°.8$. Dziewulski[8] found by applying Bravais's method to 279 stars $D+44°.2$; but by rejecting all stars with radial velocities exceeding 80 km/sec he found $D+25°.9$. Strömberg's results, however (*i. e.*), do not give any support to this as they show no systematic change in D with V_0. We seem therefore unable to escape the conclusion that these excessive velocities cannot alone be responsible for the higher value of D.

With regard to the vertex of star streaming, Kapteyn's correction term in $\mu\delta$ would change Eddington's vertex from $A=94°$, $D=+12°$ to about $A=87°$, $D=+19°$. From stars with large proper motion Dyson found 88° and +24°; Beljawski 86° and 24°; Comstock[9] from faint stars 87° and +28°; which all point strongly in favor of Kapteyn's correction. The writer, however, found from his 700 stars, by applying Bessel-Kobold's method after correcting for the solar motion, 105° and +12°, the value of D agreeing perfectly with Eddington's.

The large proper motions thus seem unable to give conclusive evidence as to the reality of Kapteyn's correction to Boss's proper motions in the resulting values for the declinations of either the apex of the solar motion or the vertex of star streaming.

If we now consider apex determinations for stars of different spectral class we should expect, according to Kapteyn's theory, that the B stars with their small proper motions would

[8] *Extr. Bull. Acad. Cracovie,* cl. sc. math. A juin, 1915.
[9] *Astr. Jour.,* **28,** 49, 1913.

show the highest value of D and also that the smallest D would occur for the Boss stars at spectral class F or G. The results do not justify these expectations. It is true that both Boss[10] himself and Raymond (*i. e.*) find D decreasing from B to A and F but both find a very much larger abrupt increase from F to G-K-M, for which three classes D is almost constant. Both investigators thus find the difference:

$$D\ (G\text{-}M) - D\ (Oe\text{-}F)$$

to be ten or twelve degrees, at the same time that their D for early type stars is close to the D derived from radial velocities. Dyson and Thackeray[11] find a difference in the same sense for the Groombridge stars.

A method of testing qualitatively the reality of Kapteyn's correction term may be suggested in the following: Consider the relation between mean parallax, proper motion and apparent magnitude, which may be expressed as a linear relation between $M=m+5+5\ \log\ \pi$ and $H=m+5+5\ \log\mu$. Furthermore consider two groups of stars, preferably giants of the same spectral class, the same absolute magnitude, galactic latitude and distance from the apex but different declinations. Then the value of c in the relation $M=a+c\,H$ must be different in the two cases, since the correction term $\Delta=G\cos\delta$ will affect the stars with lower declinations more than it will those of higher declinations.

Of the two recent determinations of the solar apex by means of radial velocities, Strömberg's which is based on the most homogeneous material gives the declination of the apex with a probable error of 3°.4. Determinations by means of proper motions are still largely dependent on the method used, as we see plainly in the case of the solutions made for the Boss stars. The declinations for these determinations vary from +31°.5 (Raymond) to +36°.2 (Eddington). We may therefore say that the errors in the proper-motion determinations are probably not less than the one found from radial velocities, and the mean error of the difference D (*p. m.*)—D (*r. v.*) not less than 7°.6, i. e., of the same size as the difference itself.

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[10] *Astr. Jour.*, **26**, 187, 1911.
[11] *Mon. Not. R. A. S.*, **65**, 428, 1905.

An interesting contribution to the question of systematic errors in Boss's proper motions may be made by considering the results of latitude work. An error of 0″.013 cos δ in the annual proper motions accumulates to 0″.4 cos δ in thirty years, as variation of latitude. I am permitted by Prof. R. H. Tucker to state here, that no such variation has been found by him in the latitude of the Lick Observatory, and I think we can say that it has not been found at any of the observatories where meridian circle and fundamental work have been done. For the latitude stations the question has recently been examined by Lawson[12], Lambert[13] and Schlesinger[14]. The former derived an increase in the latitude of Ukiah of the same order as that demanded by Kapteyn's corrections. The proper motions used by him are, however, based on the Cohn-Auwer's system and Schlesinger[14] showed that this steady increase in latitude almost disappeared when the proper motions were reduced to Boss's system. In fact, the difference Cohn-Auwers minus Boss is +0″.0087 ± 0″.0011 that is, almost of the same size as Kapteyn's correction term (0″.0113 for this latitude).

From the foregoing considerations we conclude that a correction of 0″.013 cos δ to the Boss proper motions in declination as advocated by Kapteyn clears up several discordances that otherwise seem to be left unexplained. As, however, other facts seem to contradict the existence of such a large correction, it seems desirable to look for an explanation of these facts elsewhere.

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[12] *Bull. Dept. Geol. Univ. Calif.*, No. **7**, Vol. **2.**
[13] *Jour. Wash. Acad. Sci.*, **12**, 28, 1922.
[14] *Astr. Jour.*, **34**, 39, 1922.